Quantification of Mitral Regurgitation: New Guidelines

Sunil Mankad, MD, FACC, FCCP, FASE
Associate Professor of Medicine
Mayo Clinic College of Medicine
Director, Transesophageal Echocardiography
Associate Director, Cardiology Fellowship
Mayo Clinic, Rochester, MN
mankad.sunil@mayo.edu
@MDMankad

DISCLOSURE

Relevant Financial Relationship(s)
None

Off Label Usage
None

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Confusion: Unclear Terminology

1) Trivial
2) Trace
3) Mild
4) Mild to moderate
5) Moderate
6) Moderate to severe
7) Moderately Severe
8) Severe
9) Industrial Strength
10) Torrential

Semi-Quantification

- 1+
- 1-2+
- 2+
- 2-3+
- 3+
- 3-4+
- 4+

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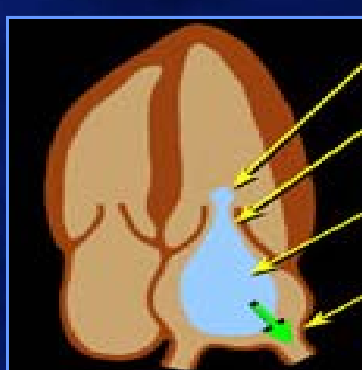
Mitral Regurgitation Has Four Hallmarks



Flow Convergence

Flow Acceleration

Turbulence → Jet Area

Downstream

Adapted from Echo in Context. Kisslo et al.

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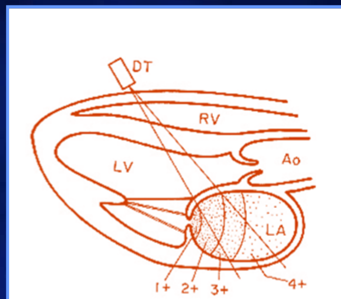
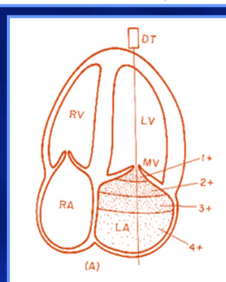
MR Jet Area Semi-Quantification





Adapted from Echo in Context – Kisslo et al.

MAYO CLINIC Adapted from Nanda N. Textbook of Color Doppler

Quantification of MR by Jet Area

Mild	Moderate	Severe
Small Central Jet (usually < 4 cm²) < 20% of LA Area	20-40% of LA Area	Large Central Jet (usually > 10 cm²) > 40% of LA Area

- Zoghbi WA et al. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography. *J Am Soc Echocardiogr* 2003;16:777-802.
- Zoghbi WA et al. *J Am Soc Echocardiogr.* 2017

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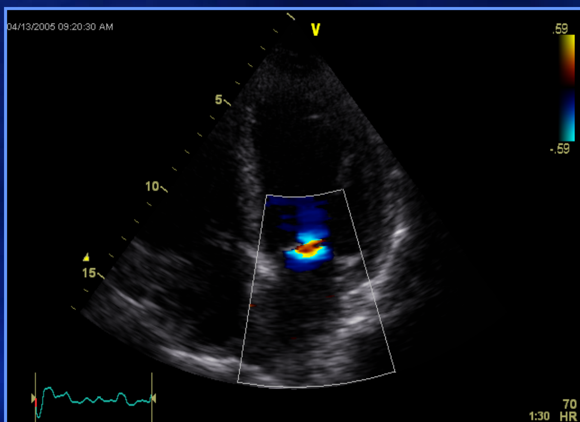
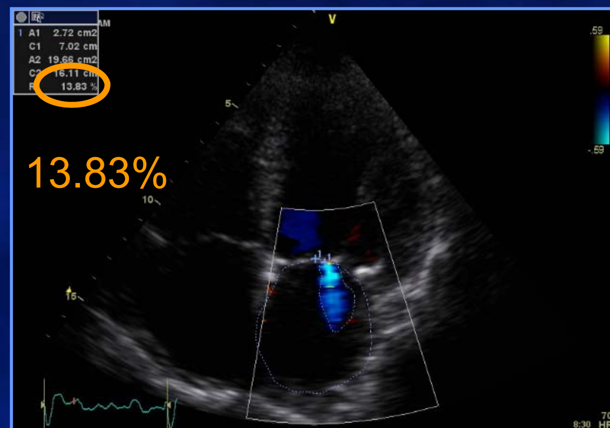
Mild MR





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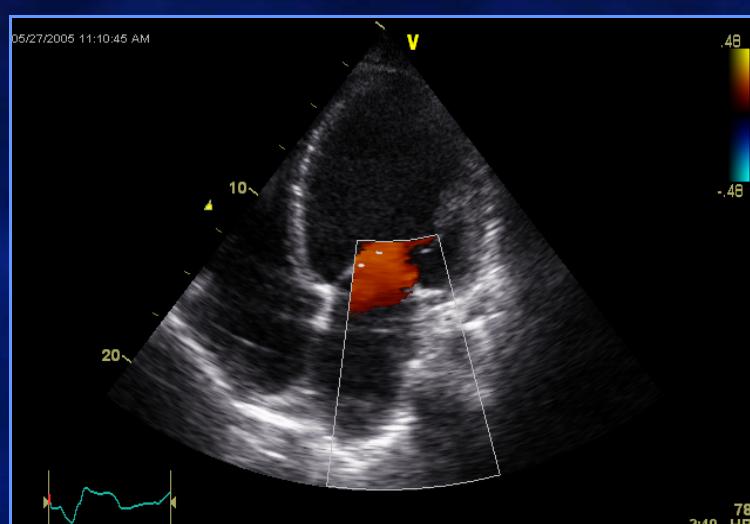
How Bad is the Mitral Regurgitation?

1. Mild
2. Moderate



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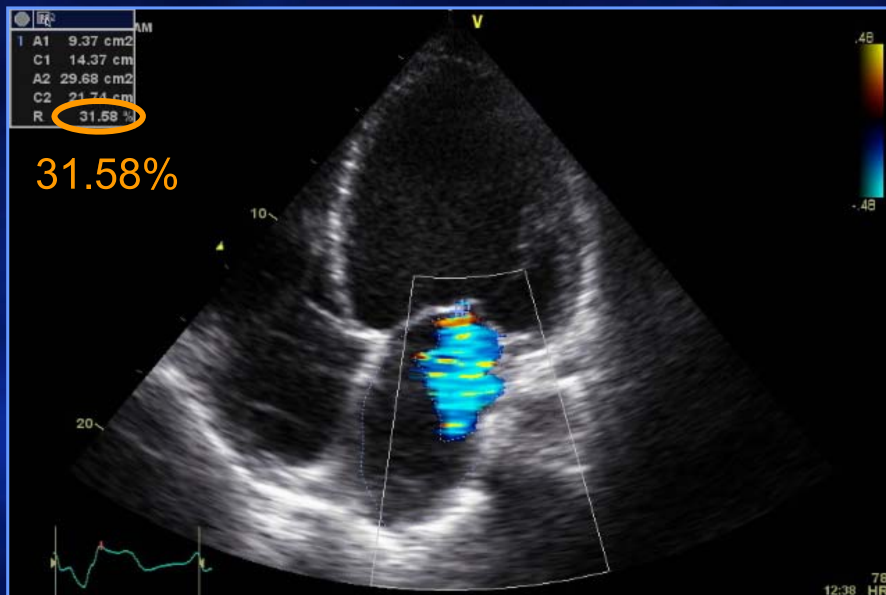
How Bad is the Mitral Regurgitation?

1. Mild
2. Moderate



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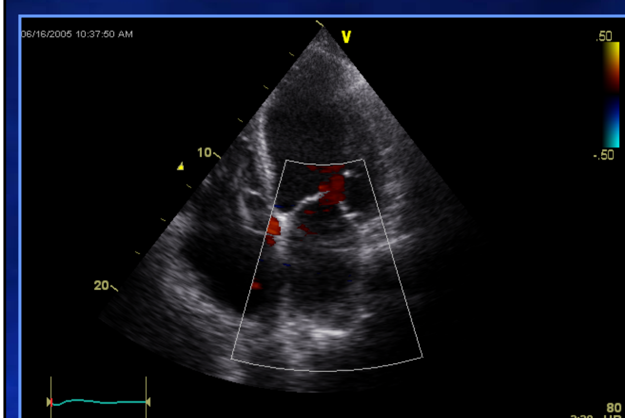
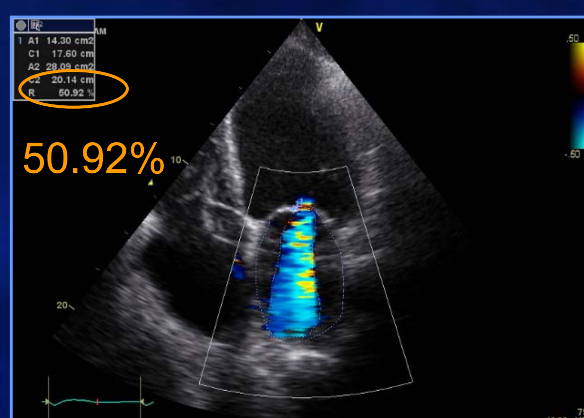
Severe MR





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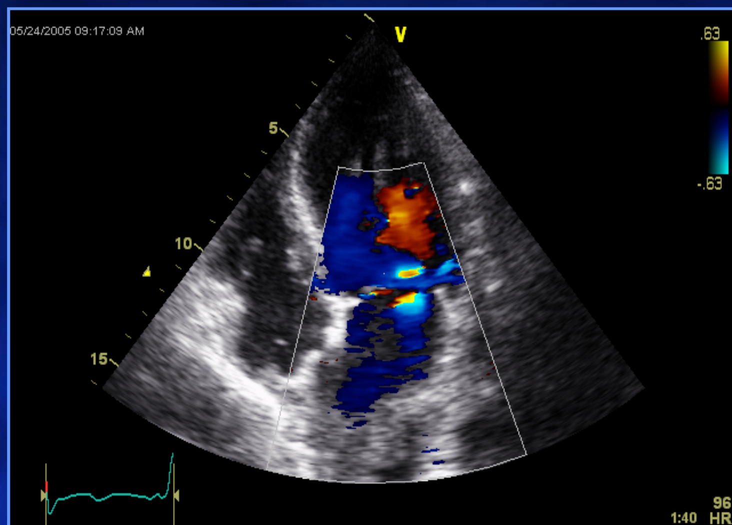
Eccentric Mitral Regurgitation: Coanda Effect



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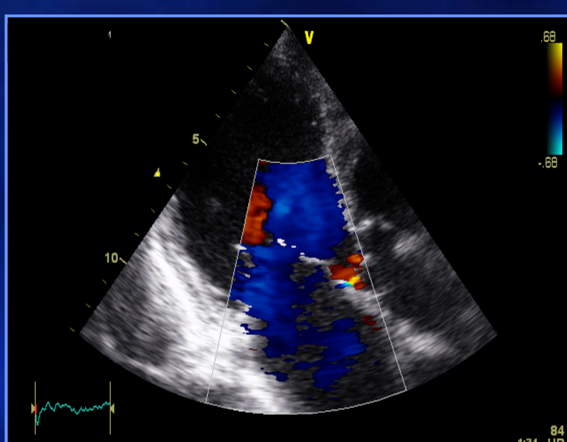
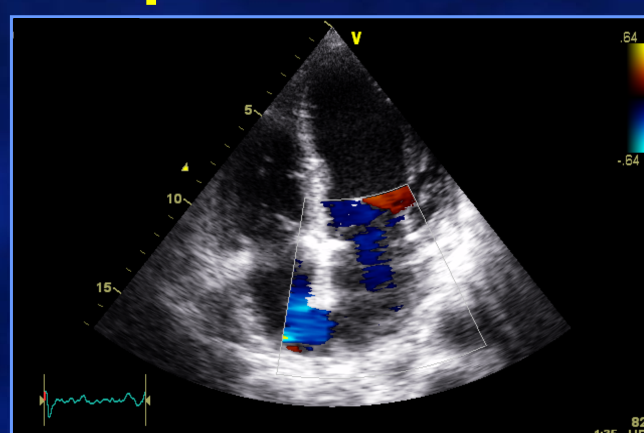
Importance of Looking at Eccentric MR Jets in Multiple Views





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Problems with Jet Area

- Affected by instrumental factors
  - Pulse Repetition Frequency
    - Nyquist limit should be > 50-70 cm/sec
  - Color Gain
    - Gain set so that random color speckling does not occur in non-moving regions

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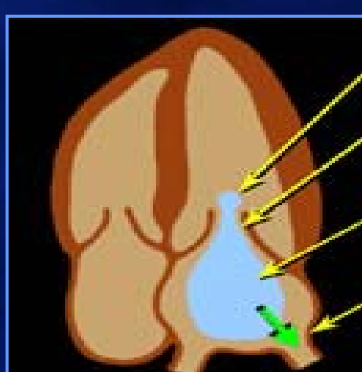
Regurgitation Has Four Hallmarks



Flow Convergence

Flow Acceleration → Vena Contracta

Turbulence

Downstream

Adapted from Echo in Context. Kisslo et al.

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Vena Contracta

- Narrowest portion of a jet that occurs at or just downstream from the orifice

- **Vena Contracta Width**
  - Mild < 0.3 cm
  - Moderate 0.3-0.69 cm
  - Severe > 0.7 cm
  - Biplane Severe > 0.8 cm

Zoghbi WA et al. *J Am Soc Echocardiogr* 2003;16:777-802.

Zoghbi WA et al. *J Am Soc Echocardiogr*. 2017

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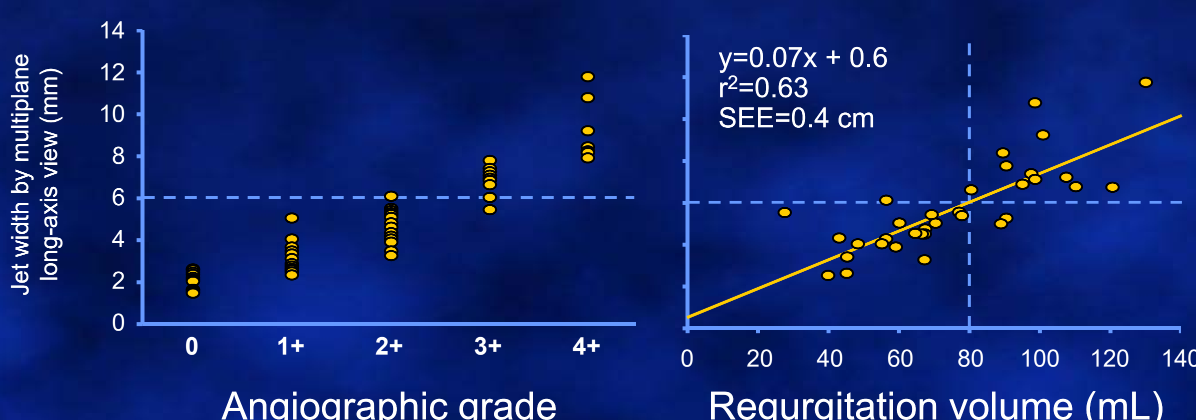
Mitral Regurgitation

Transesophageal Echo Long Axis

Vena Contracta vs Angiographic Grade

Vena Contracta vs Regurgitant Volume



Adapted from Grayburn PA: AJC 74, 1994

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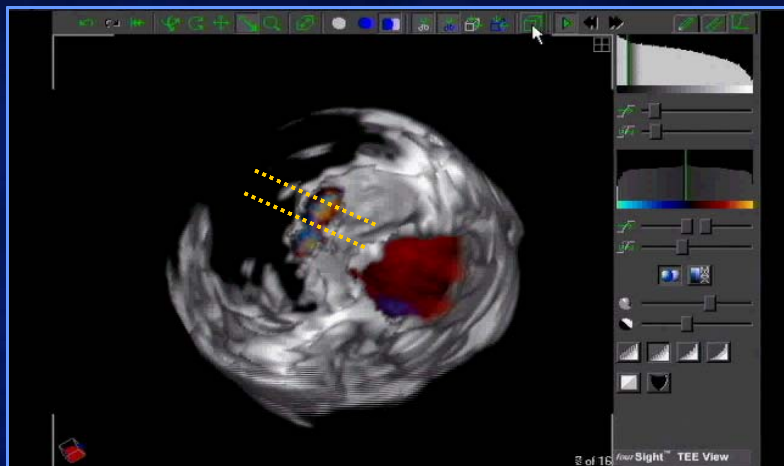

Problems with Vena Contracta

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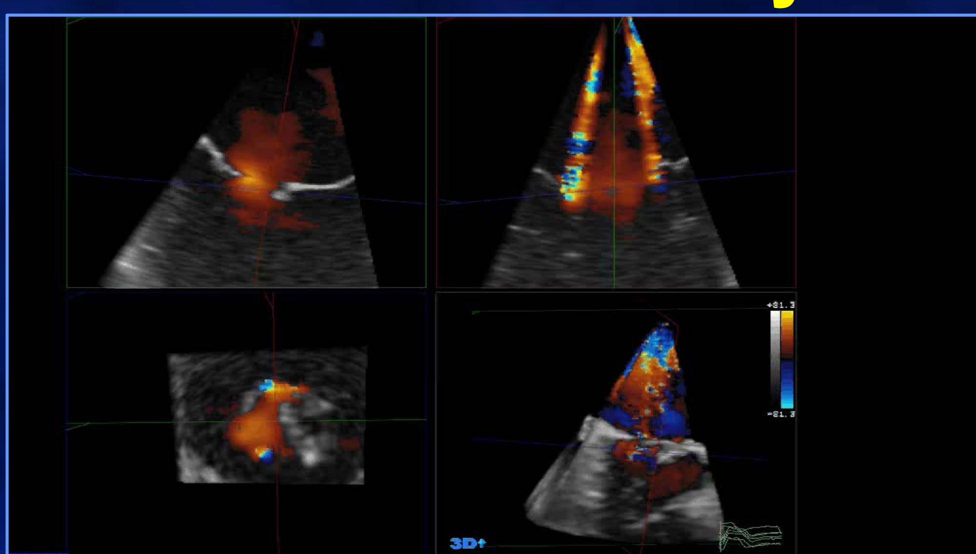
Vena Contracta Area by 3D TEE



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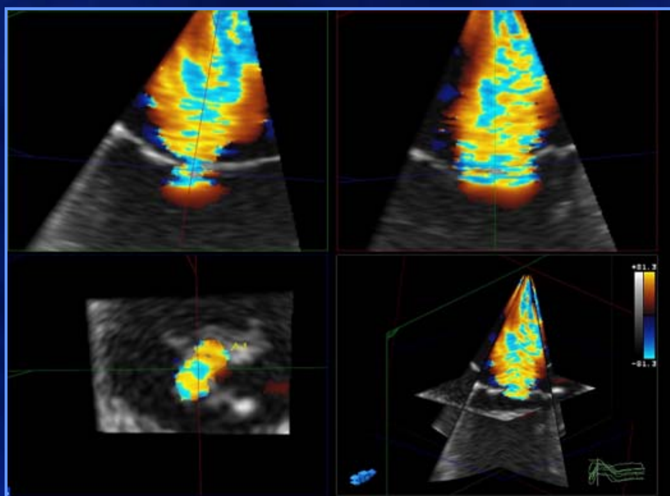
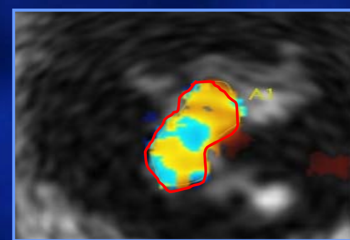
Vena Contracta Area by 3D TEE





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Valvular Regurgitation
Quantitation

- Regurgitant volume (RV)
- Effective regurgitant orifice (ERO)
- Regurgitant fraction (RF)

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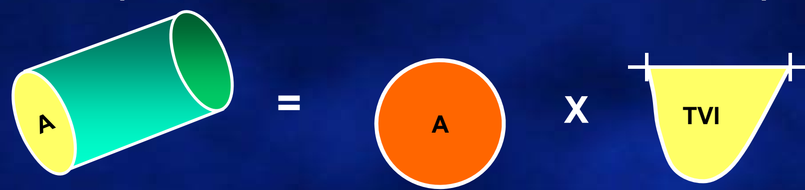
Continuity Equation

Quantitative Hemodynamics
(Conservation of Mass Principle)



Stroke volume Area X TVI

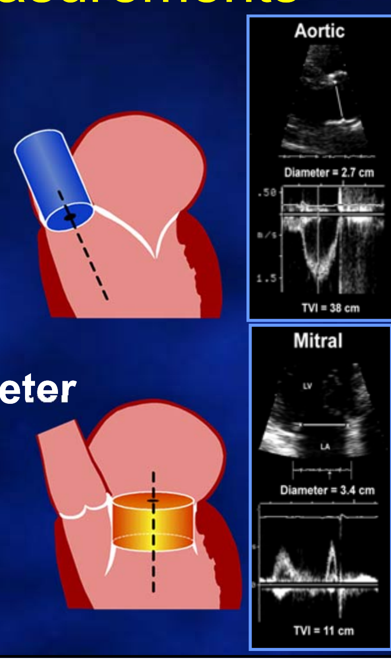
Four Measurements

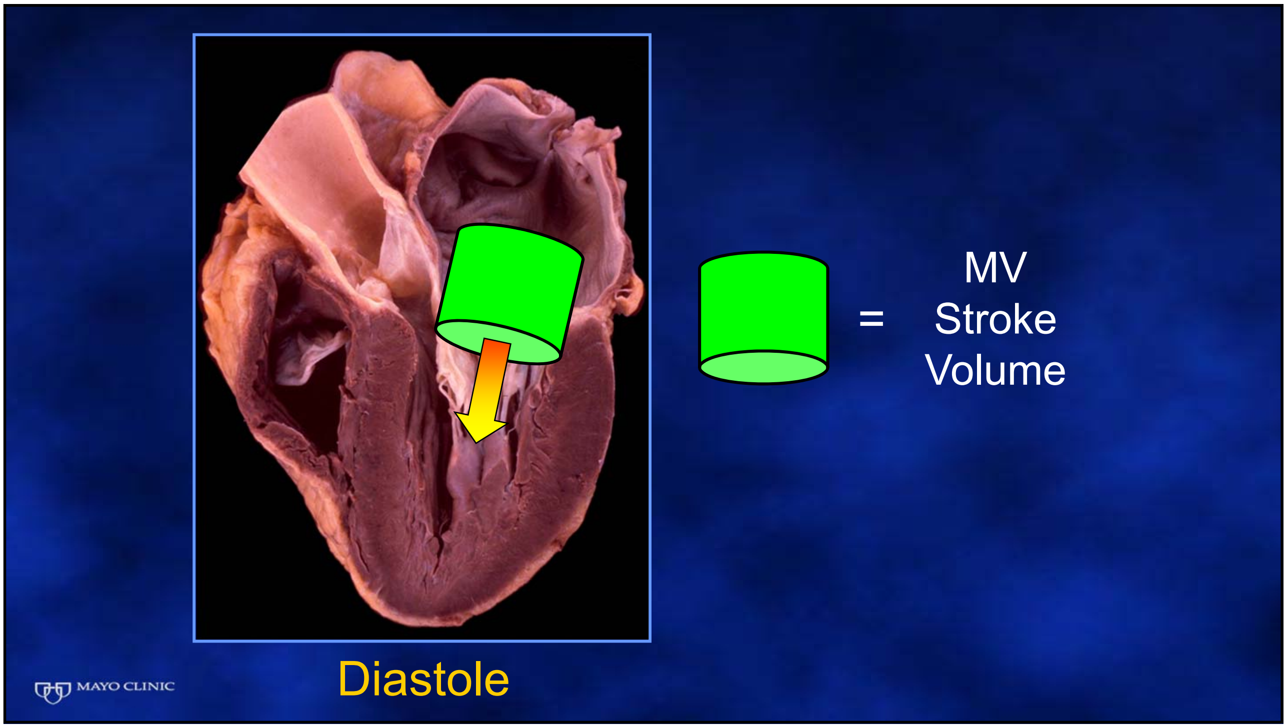
- LVOT Diameter
- LVOT TVI

SV_{LVOT}

- Mitral annulus diameter
- Mitral annulus TVI

SV_{MV}





MV
Stroke
Volume
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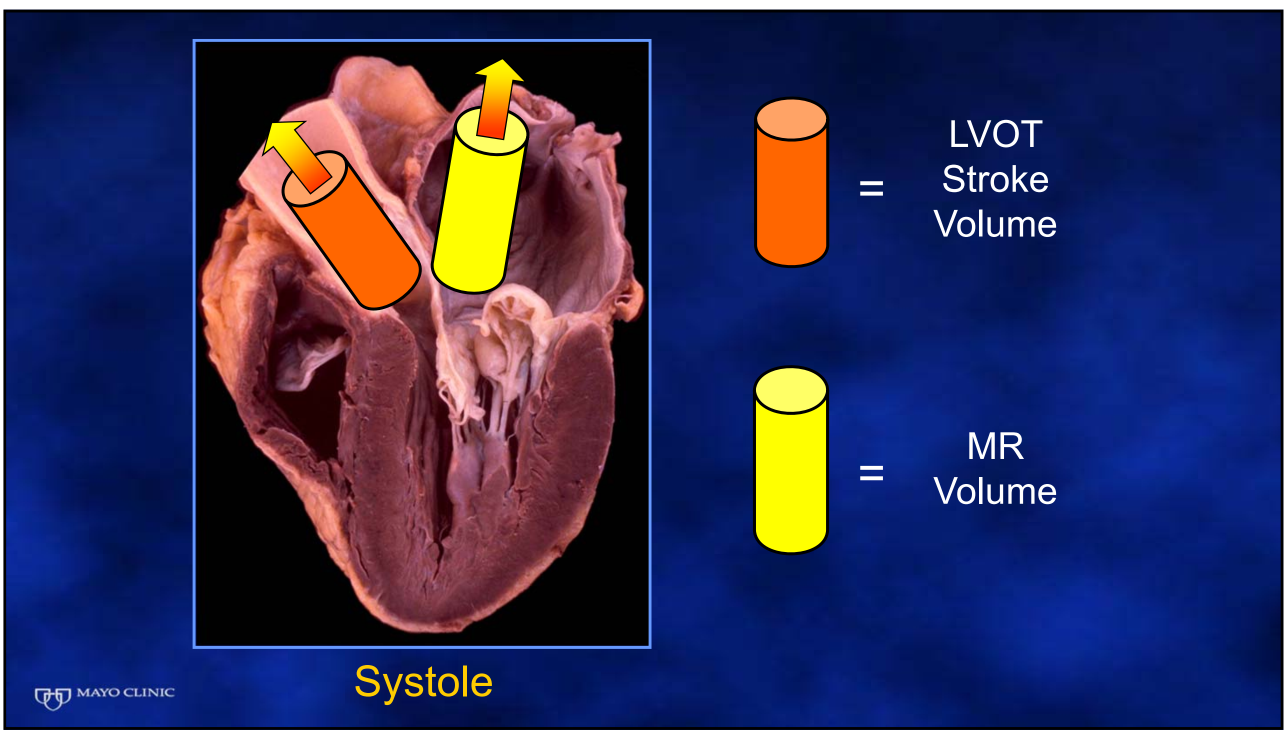
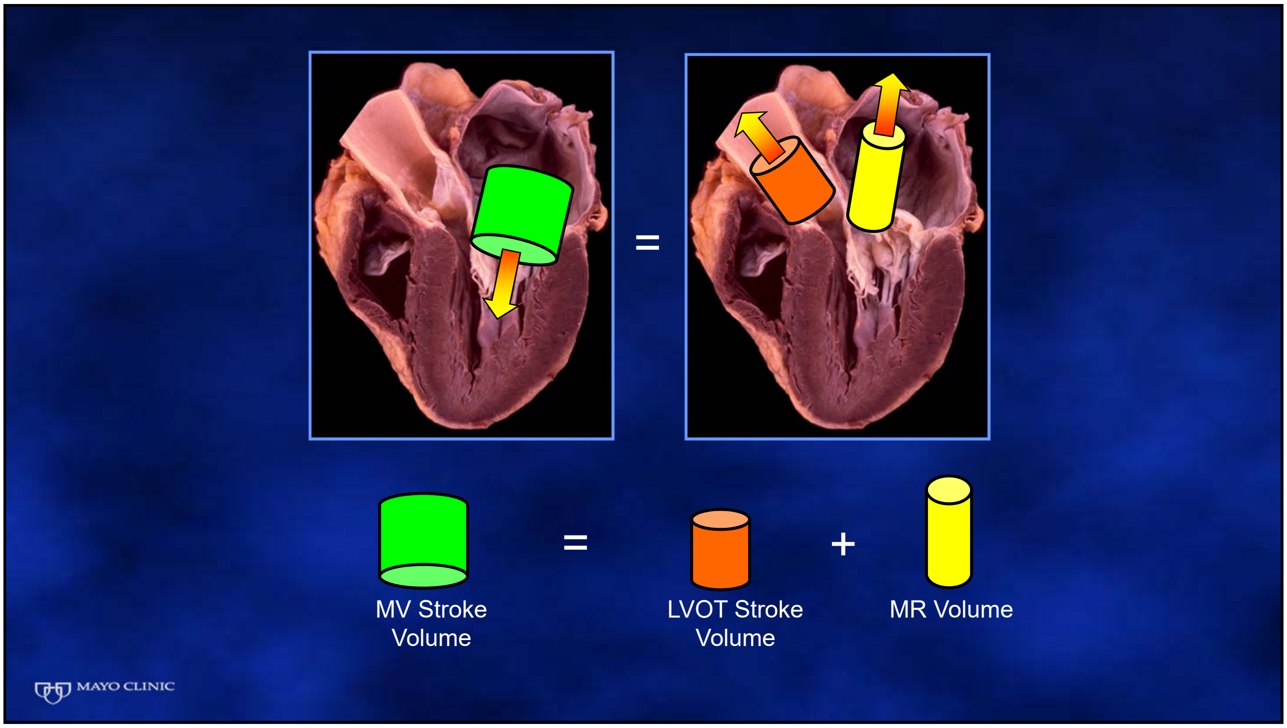
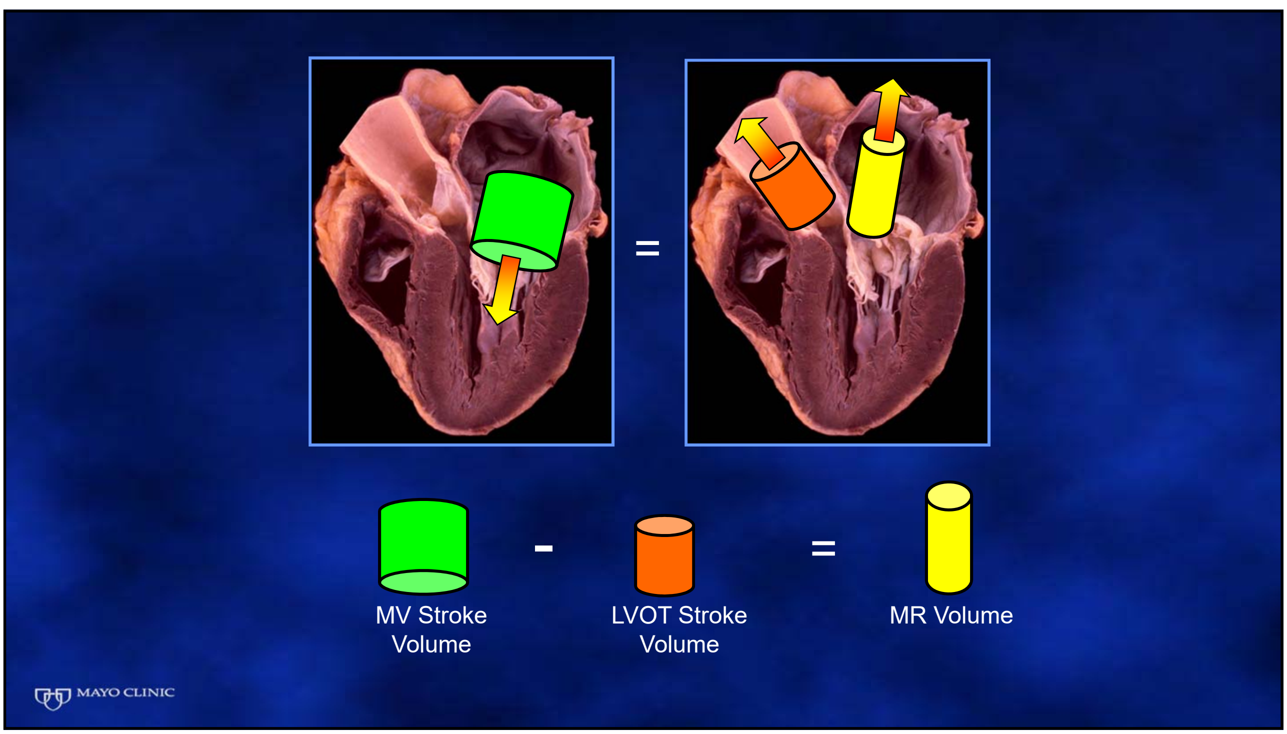
Diastole



LVOT
Stroke
Volume
MR
Volume
MAYO CLINIC
Systole


=
=
+
MV Stroke Volume
LVOT Stroke Volume
MR Volume
MAYO CLINIC


=
-
=
MV Stroke Volume
LVOT Stroke Volume
MR Volume
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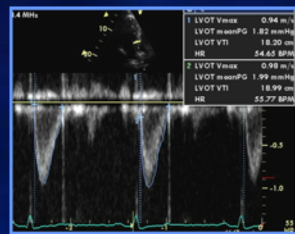
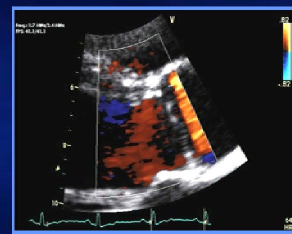
Step 1: Calculate LVOT Stroke Volume


LVOT diameter = 2.6 cm


LVOT TVI = 18 cm


No AR

LVOT Stroke Volume $= \pi\,(D/2)^2 \times 18\text{ cm}$

$= 0.785\,(2.6\text{ cm})^2 \times 18\text{ cm}$

$= 96\text{ cm}^3$

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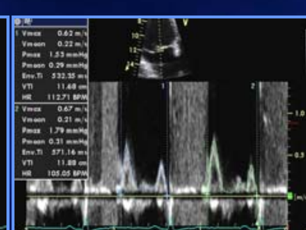
Step 2: Calculate MV Stroke Volume


MV diameter = 4.1 cm


MV Annular TVI = 12 cm

MV Stroke Volume $= 0.785\,(4.1\text{ cm})^2 \times 12\text{ cm}$

$= 158\text{ cm}^3$

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Step 3: Calculate MR Volume

MV Stroke Volume - LVOT Stroke Volume = MR Volume

$158\ cm^3 - 96\ cm^3 = 62\ cm^3$

Step 4: Calculate Regurgitant Fraction (RF)

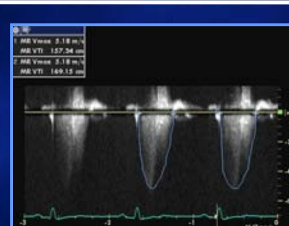
$$\text{Mitral RF} = \frac{\text{MR Volume}}{\text{MV Stroke Volume}} = \frac{62\ cm^3}{158\ cm^3} = 40\%$$

Step 5: Calculate MR ERO

E ffective
R egurgitant
O rifice

MR Volume

62 cm^3



MR TVI

(163 cm)

$$\text{ERO} = \frac{62\ \text{cm}^3}{163\ \text{cm}} = 0.38\ \text{cm}^2$$

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Quantitation of Mitral Regurgitation

	Mild	Moderate		Severe
MR Volume (cm^3/beat)	<30	30 - 44	45 - 59	≥ 60
Regurgitant Fraction (%)	<30	30 - 39	40 - 49	≥ 50
ERO (cm^2)	<0.20	0.20-0.29	0.30-0.39	≥ 0.40

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Zoghbi WA, et al. *J Am Soc Echocardiogr* 2017

Quantitation of Valvular Regurgitation
Continuity Method: Potential Pitfalls

- Incorrect Doppler alignment to flow ($\theta > 20^{o}$)
- Incorrect sample volume placement:
  - Place at annulus, not leaflet tips
- Incorrect annular measurement: $(error)^2$
  - Mitral annular calcification (MAC)
- Failure to trace modal velocity (especially MV)
- Geometric assumptions of circular annulus
  - (LVOT – excellent, MV - good, TV - poor)
- Aortic regurgitation > mild (use RVOT instead)
- Arrhythmia; inadequate data averaged

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Regurgitation Has Four Hallmarks

Flow Convergence → PISA

Flow Acceleration

Turbulence

Downstream

Adapted from Echo in Context. Kisslo et al.

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What is PISA ?

- **Derived from the hydrodynamic principle stating that, as blood approaches a regurgitant orifice, its velocity increases forming concentric, roughly hemispheric shells of increasing velocity and decreasing surface area**

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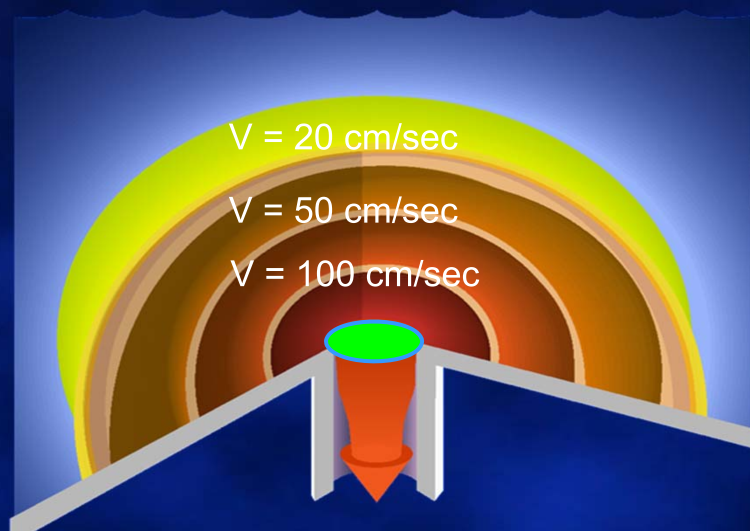
Flow Convergence

P roximal
I sovelocity
S urface
A rea



V_{MR} = 500 cm/sec

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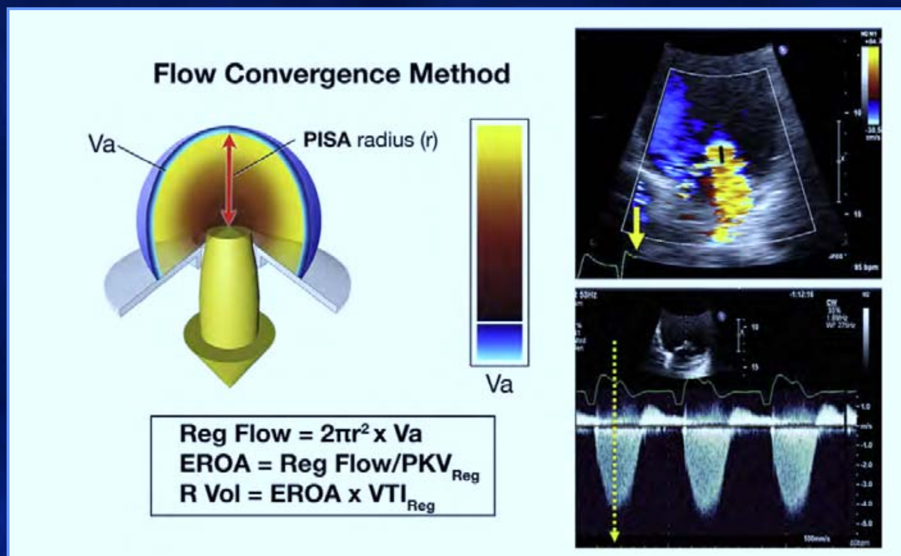
PISA Calculations



Adapted from Zoghbi WA et al. *J Am Soc Echocardiogr*. 2017

Locating the Color Flow Convergence

- **Zoom region of interest (Decreases error of radius measurement)**
- **Shift color Doppler baseline in the direction of the regurgitant jet**
- **Baseline shift to obtain an optimal hemispheric flow convergence signal for PISA measurement**

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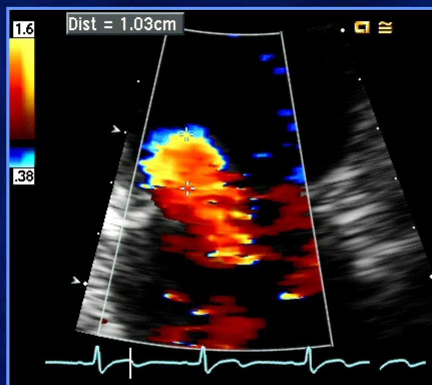
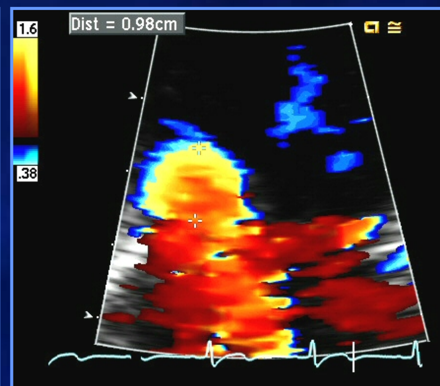
Zoom In As Tight As You Can





- Larger zoom box
- Smaller zoom box

- Courtesy of Leslie Elvert, B.S., R.D.C.S.

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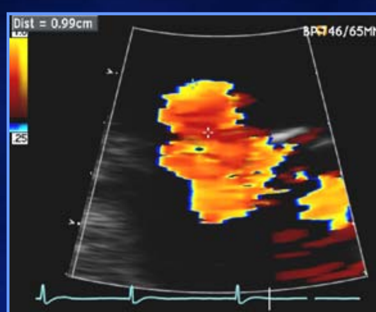
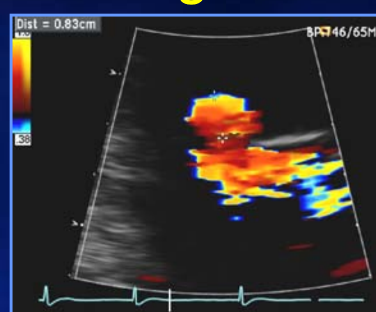
What is the best aliasing velocity?





- Alias Vel. 25 cm/s
- Radius 0.99 cm
- ERO 0.32 cm2
- Reg Vol 44 cc

- Alias Vel. 38 cm/sec
- Radius 0.83 cm
- ERO 0.35 cm2
- Reg Vol 47 cc

- Courtesy of Leslie Elvert, B.S., R.D.C.S.

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Advantages of PISA Method

- Can be used in presence of other valvular regurgitation or shunts
- Can be used in presence of valve stenosis or prosthetic valves
- Uses fewer variables

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Quantitation of Mitral Regurgitation

	Mild	Moderate		Severe
MR Volume (cm^3/beat)	<30	30 - 44	45 - 59	≥ 60
ERO (cm^2)	<0.20	0.20-0.29	0.30-0.39	≥ 0.40
Vena Contracta Width (cm)	< 0.3	0.3 - 0.69		≥ 0.7

Zoghbi WA, et al. J Am Soc Echocardiogr 2017

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Simplified Approach to PISA (ERO)

- ERO = $2\pi \cdot r^2 \cdot$ V/Vmax of MR
  = $6.28 \cdot r^2 \cdot$ V/Vmax of MR

- If V/Vmax of MR can be adjusted to 1/12, then ERO = 6.28/12 x r^2
  = 0.5 x r^2

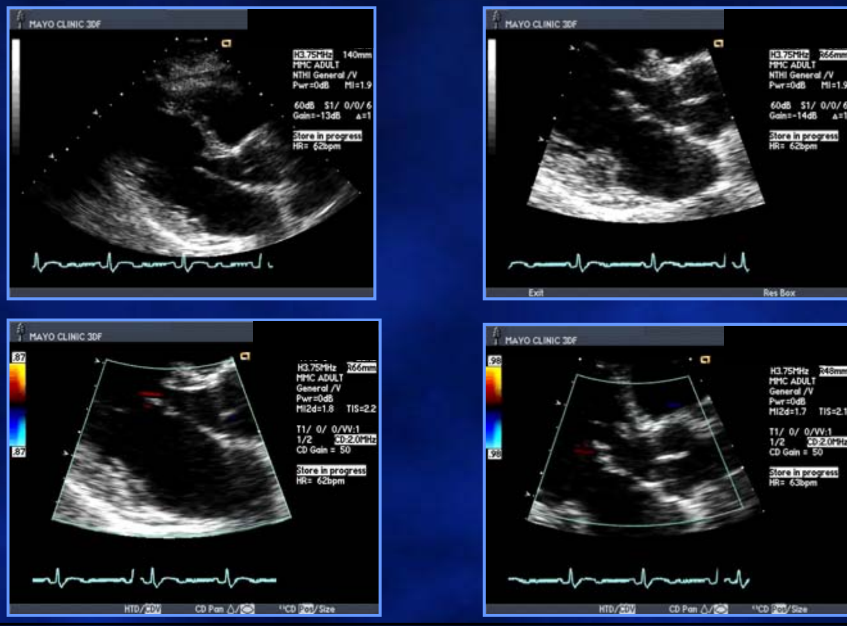
Aliasing velocity set at 40 cm/sec assuming MR maximum velocity ≅ 500 cm/sec

Pu M et al. *J Am Soc Echocardiog* 2001

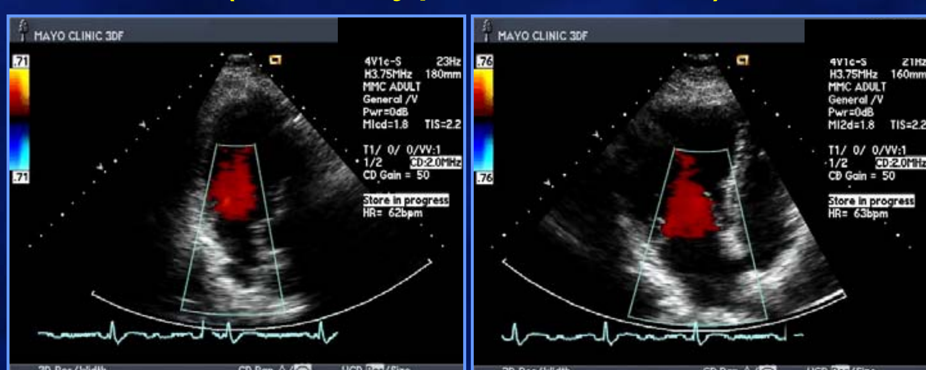
Simplified PISA (ERO)

- Examples
  - r = 0.4 cm; r^2 = 0.16 cm^2; ERO = 0.08 cm^2
  - r = 0.6 cm; r^2 = 0.36 cm^2; ERO = 0.18 cm^2
  - r = 0.8 cm; r^2 = 0.64 cm^2; ERO = 0.32 cm^2
  - r = 0.9 cm; r^2 = 0.81 cm^2; ERO = 0.4 cm^2
  - r = 1.0 cm; r^2 = 1.0 cm^2; ERO = 0.5 cm^2

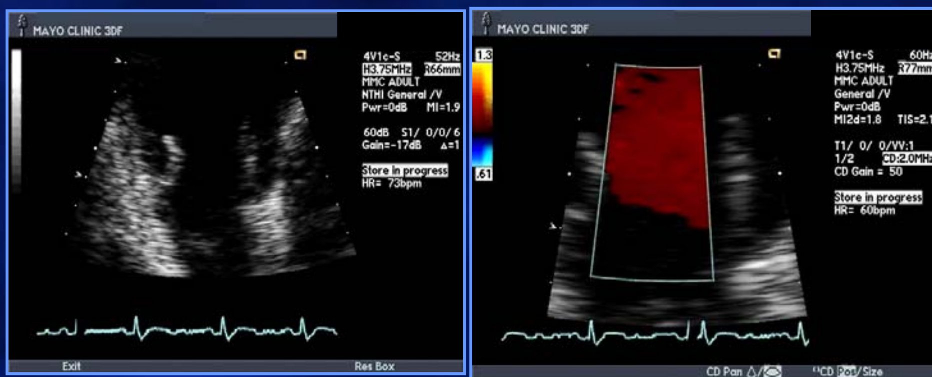
48 y/o Housewife: Heart murmur, dyspnea



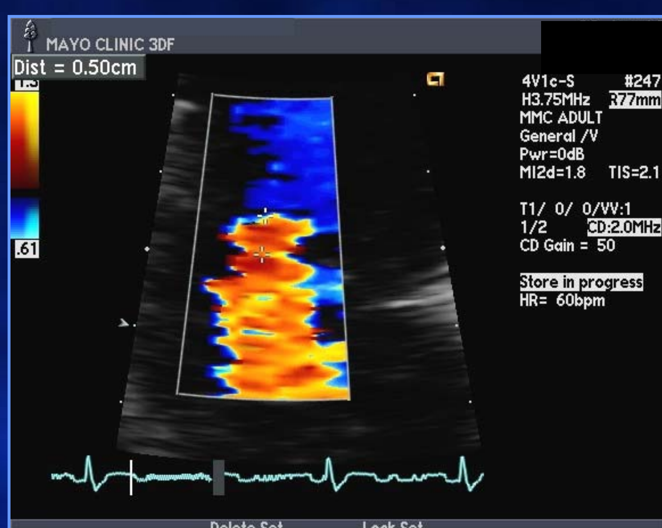
Apical Color Views: Mayo Clinic Format (ASE Type B Format)



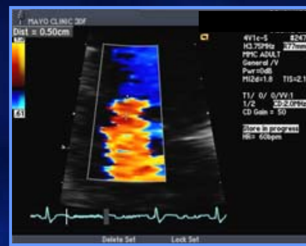
Mayo Clinic Format
(ASE Type B Format)



PISA R = 0.5 cm; Aliasing velocity 61 cm/sec



Step 1: Calculate proximal MR flow

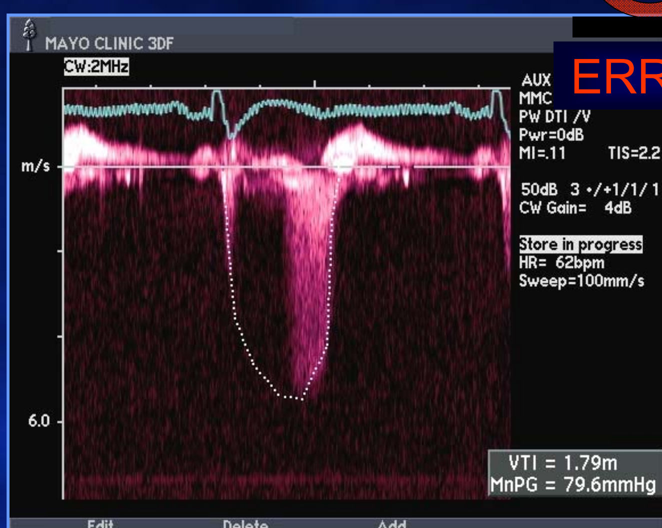


$$Flow_{MR} = Area_{PISA} \times Velocity_{Alias}$$
$$= 2\pi \times R^2 \times V_{Alias}$$
$$= 6.28 \times (0.5cm)^2 \times 61\ cm/sec$$

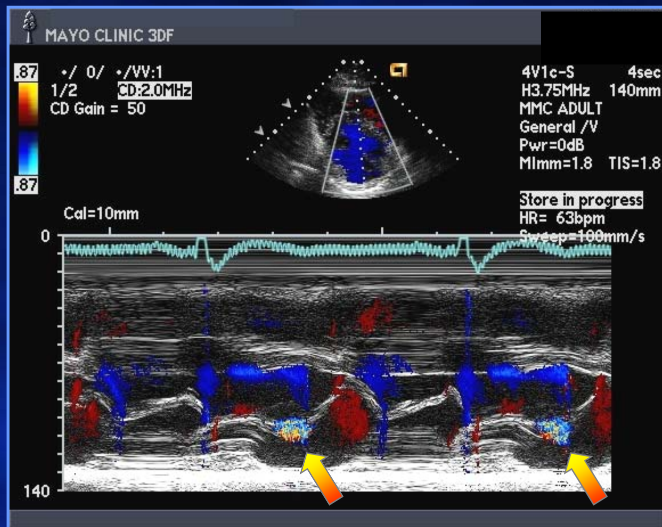
$$Flow_{MR} = 96\ cm^3/sec$$

MR Peak Velocity 570 cm/sec; TVI = 179 cm

ERROR



Color M-Mode: MVP and MR



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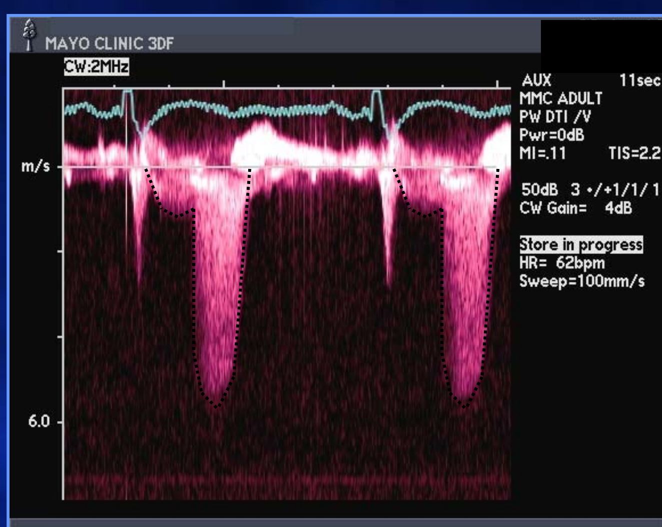
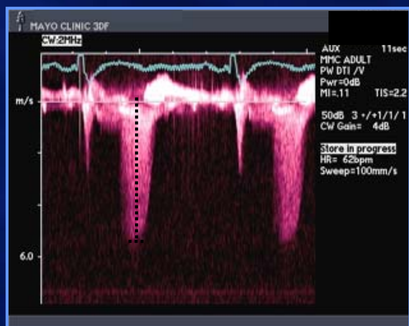
MR Peak Velocity 570 cm/sec; TVI = 127 cm



91NM

Step 2: Calculate the mitral ERO



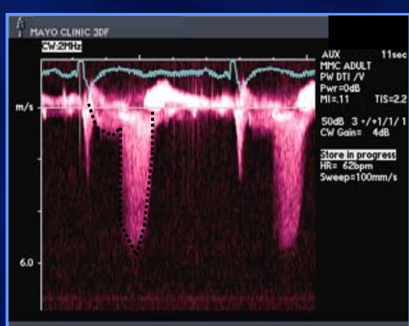
Velocity_{MR} = 570 cm/sec

$$\text{ERO} = \frac{\text{Flow}_{MR}}{\text{Velocity}_{MR}}$$

$$= \frac{96\ \text{cm}^3/\text{sec}}{570\ \text{cm/sec}}$$

$$= 0.17\ \text{cm}^2$$

Step 3: Calculate MR volume



TVI_{MR} = 127 cm

Volume_{MR}

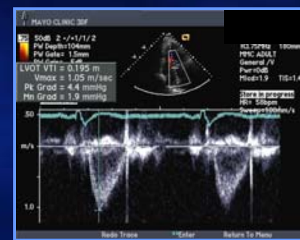
$= \text{ERO} \times \text{TVI}_{MR}$

$= 0.17\ \text{cm}^2 \times 127\ \text{cm}$

$= 22\ \text{cm}^3$

Step 1: Calculate LVOT Stroke Volume

LVOT Diameter = 2.2 cm



LVOT TVI = 20 cm

LVOT Stroke Volume $= 0.785\ (2.2\ \text{cm})^2 \times 20\ \text{cm}$

$= 76\ \text{cm}^3$

Step 2: Calculate MV Stroke Volume

MV Annulus = 3.6 cm

MV Annulus TVI = 10 cm

MV Stroke Volume $= 0.785\ (3.6\ \text{cm})^2 \times 10\ \text{cm}$

$= 102\ \text{cm}^3$

Step 3: Calculate MR Volume

MV Stroke Volume - LVOT Stroke Volume = MR Volume

$$102 \text{ cm}^3 - 76 \text{ cm}^3 = 26 \text{ cm}^3$$

Step 4: Calculate Regurgitant Fraction (RF)

$$\text{Mitral RF} = \frac{\text{MR Volume}}{\text{MV Stroke Volume}} = \frac{26 \text{ cm}^3}{102 \text{ cm}^3} = 25\%$$

Step 5: Calculate MR ERO

Effective Regurgitant Orifice =

MR Volume (26 cm^3)

MR TVI (127 cm)

$$\text{ERO} = \frac{26\ \text{cm}^3}{127\ \text{cm}} = 0.20\ \text{cm}^2$$

Problems with PISA

- **Sub-optimal flow convergence**
  - **Non-hemispheric flow**
- **Multiple MR jets**
- **Some eccentric jets may impinge on hemisphere**
- **LVOT obstruction may distort the isovelocity convergence zone**
- **PISA is dynamic during systole, timing is crucial**
- **PISA is too complicated for routine clinical use**
- **PISA just doesn't work**
  - **Cluelesly Reasoned Assumptions Principle**

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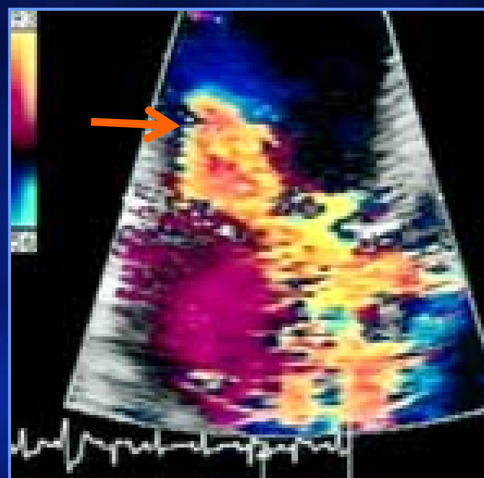
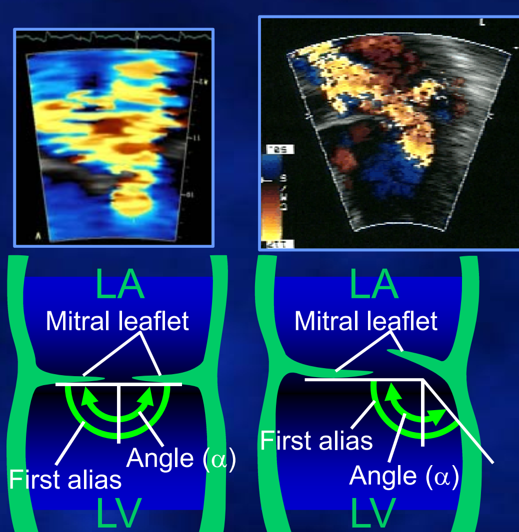
Sub-optimal Flow Convergence



Non - Hemispheric Flow Convergence: Wall Impingement



$$\text{ERO}= \frac{\pi \times r^2 \times Av}{MR\ Vmax} \times \frac{\alpha}{180}$$

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Severe Mitral Regurgitation
- Supportive Signs

Pulmonary Vein Systolic Reversal of Flow

- Enlarged LA
- Enlarged LV
- E wave velocity > 1.2 m/sec

Final Points

- **Mild, well visualized, central jet = MILD**
- **If suspect more that mild, analyze**
- **Use all available info, no method is perfect**
  - **Cardiac MRI or LV Angiography if still in doubt after echocardiography**
- **Learn to quantify**
- **Responsibility to patients and colleagues to produce a report closest to the truth**

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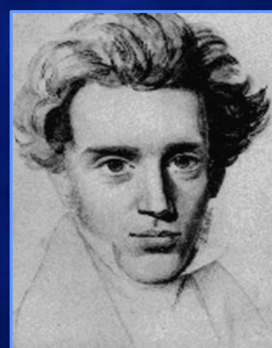
"To dare is to lose one's footing momentarily, not to dare is to lose oneself"



- Soren Kierkegaard

Thank You!

mankad.sunil@mayo.edu
@MDMankad